THE AMERICAN MINERALOGIST

JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

Vol 12 JANUARY, 1927 No. 1

A CHEMICAL STUDY OF THE YELLOW INCRUSTATIONS ON THE VESUVIAN LAVA OF 1631[1]

F. ZAMBONINI AND G. CAROBBI, *University of Naples.*
Abstract by HENRY S. WASHINGTON, *Geophysical Laboratory, Carnegie Institution of Washington.*

INTRODUCTION

In 1879 Arcangelo Scacchi[2] described yellow crusts that coat the walls of crevices in the massive lava flows of 1631 at Vesuvius. He suggested that there was present a possibly new element, much like vanadium, which he provisionally named *vesbium*, after an ancient name of Vesuvius. To the substance forming the crusts, which he thought to be a vesbiate of aluminum, he gave the name *vesbine (vesbina)*. Most of the chemical reactions on which he based the distinction between vesbium and vanadium are not decisive, and others are explained by the presence of various elements that have been revealed by more recent study. Indeed, Scacchi himself was later convinced of the identity of vesbium with vanadium.

For many years no further study of vesbine was made, the chief reasons being the rarity and the small quantity of the material and the difficulty of obtaining it in a state of purity. In 1910 Zambonini,[3] from study of a very minute quantity of material, not sufficient for complete analysis, showed definitely that vesbine is a vanadate. He thought that the base was probably uranium and that the mineral was allied to carnotite, this conclusion being based on certain chemical reactions and on the radioactivity of the specimen.

Some years later De Luise[4] published an analysis of vesbine with the following results: V_2O_5 11.83, Cl 7.16, PbO 5.77, CuO

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[1] This résumé and, in part, literal translation, of a somewhat lengthy and detailed paper by the two authors, (to be published in the Memoirs of the Academy of Naples), has been made at the request of Professor Zambonini. It is published in the American Mineralogist, in accordance with his desire, as a mark of his esteem for the Society. (H. S. W.)

[2] A. Scacchi: *Atti Accad. Sci. Napoli*, 13 December, 1879.

[3] Zambonini: MINERALOGIA VESUVIANA, *Napoli*, 1910, p. 315.

[4] L. De Luise: Notizie sulla Eruzione Vesuviana del 1906, *Portici*, 1914, p. 17.

38.36, H_2O 28.87, loss and undetermined 7.16, sum 99.15. He interpreted these figures to indicate that vesbine is a mixture of vanadate of lead ("descloizite") and vanadate of copper ("volborthite"), with probably an oxychloride of copper.

As De Luise's analysis and his interpretation of the constitution of vesbine were open to criticism a new study of the material was made. The greatest difficulty in the study of vesbine is that of obtaining pure material. The yellow vesbine is almost always mixed with green, blue, and brown substances (to be investigated later), and even the purest is tenaciously attached, as a very thin film, to the surface of the lava. Separation by means of heavy solutions presents many difficulties. A very small quantity of the mineral in solution was obtained by treatment with very dilute nitric acid.

SPECTROSCOPIC STUDY

The presence of vanadium and of lead and copper, as the main constituents, was determined by qualitative chemical tests; but lead was found to be present in much larger amount than copper, contrary to De Luise's results. As there was not material sufficient for a complete analysis, for the determination of the elements present in small amounts, a spectroscopic study was undertaken. For this purpose a Hilger spectroscope was used, the region of the spectrum that was examined being from 4900 Å to 3200 Å.[5]

The spectroscopic examination demonstrated the presence in vesbine of the following elements: V, Mo, Ti, W, Cr, Cb(?), Ta(?), Pb, Cu, Al, Mn, Co(?), Zn, La, Ce, Nd, Y, Dy(?), and Er. The presence of the rare earths and of tungsten are of special interest, as these elements had not hitherto been detected at Vesuvius.

Vanadium was definitely established to be present by the identification of 76 lines, among them the two "ultimate" lines, 4408.5 and 4379.2. Molybdenum, which had previously been detected at the volcano in a Vesuvian sodalite,[6] was identified by many lines, including the "ultimate" one 3903.0. The presence of tungsten was determined by the "ultimate" lines 4302.4 and

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[5] A long list of the spectral lines observed is given in the original paper, which it is not necessary to reproduce here. (H. S. W.).

[6] Freda: *Rend. Accad. Sci. Napoli*, **1878**, pp. 88, 136; Zambonini: MINERALOGIA VESUVIANA, **1910**, p. 214.

3215.6. The presence of titanium in fumarolic salts had already been shown.[7] The presence of chromium was indicated by the two "ultimate" lines 3605.3 and 3593.4, and some others. The spectroscopic determination of columbium and tantalum is somewhat doubtful. The presence of columbium and tantalum have been noted by Prior[8] in guarinite of Monte Somma, and that of columbium in dysanalyte of Monte Somma by Zambonini.[9]

Of special interest is the very probable presence of cobalt and zinc in spectroscopic traces, two elements that have been detected only rarely and in very small quantity in the fumarolic deposits of Vesuvius. The presence of cobalt was indicated especially by the "ultimate" line 3405.1; while that of zinc is shown by the two "ultimate" lines 4722.2 and 4810.5.

The detection of some of the elements of the rare earths in vesbine is of particular interest, inasmuch as none of these seem to have been observed previously in the exhalation products of Vesuvius. That they are present is not surprising, because one of us[10] has shown that the rare earth elements are isomorphogenic with the metals of the alkaline earths and with bivalent lead, while the other author[11] has prepared synthetically pyromorphite, vanadinite, and mimetite, in which lead is partially replaced by lanthanum, and has shown the presence of some of the rare earths in natural pyromorphite. Inasmuch as vesbine contains much lead, it is clear that this may be partially replaced by rare earth metals, which have been found only in traces.

Lanthanum is certainly present, as we have identified the "ultimate" line 3949.1, and another persistent line, 3988.5, as well as others. Of cerium there were observed the two "ultimate" lines 4012.4 and 4040.8, as well as the persistent line 4186.6. The three persistent lines of neodymium, 4303.6, 4177.3, and 3951.2, were present in the spectrogram. Yttrium was identified by the "ultimate" line 3710.3, and also by the lines 3774.3 and 3600.7. The two persistent lines of erbium, 3692.4 and 3906.3, as well as others, were seen. There are also indications of the presence of lines of dysprosium and of thorium.

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[7] Coniglio: *Ann. Osserv. Vesuv.*, (3), **1**, 37, 1924; Zambonini and Coniglio: *Rend. Accad. Lincei*, (6), **3**, 521, 1926; and unpublished researches by Carobbi.

[8] Prior: *Min. Mag.*, **15**, 257, 1909.

[9] Zambonini: *Rend. Accad. Sci. Napoli*, 4 April, **1918**.

[10] Zambonini: *Riv. Min. Crist. Ital.*, **45**, 1915; *Zeit. Kryst.*, **58**, 226, 1923.

[11] Carobbi and Restaino: *Gazz. Chim. Ital.*, 56, 59, **1926**; *Rend. Accad. Sci. Napoli*, 6 and 13 Feb., **1926**.

Certain lines shown in the table, such as those of potassium, calcium, strontium, and zirconium, are attributed to particles of contaminating silicates, not to vesbine, and the spectroscopic indications of silicon and of phosphorus were very faint. Pentavalent phosphorus and arsenic were discovered later, in the course of a chemical analysis, their presence being not surprising, as vesbine is a vanadate. This is the first time that arsenic has been detected at Vesuvius.

Chemical Analysis

It is very difficult to isolate vesbine in a state of purity and in quantity sufficient for accurate chemical analysis. The mineral forms very thin films, so firmly adherent to the walls of crevices in the lava that they can be detached only along with particles of the lava or of the pneumatolytic minerals that cover it: the thicker crusts, which are more readily loosened, are usually much mixed with other substances.

Thanks to the friendly kindness of Prof. Eugenio Scacchi, who put at our disposition the rich collection of lavas of 1631 with vesbine, (collected by A. Scacchi), we were able, by scraping and scratching, to collect a couple of decigrams of very impure vesbine. Many treatments with heavy solutions yielded scarcely 6 centigrams and a half of material, which, under the microscope, was seen to be somewhat contaminated with silicates, especially feldspars and sodalite; so much so that the quantitative analysis showed the presence of 10.4 per cent of SiO_2. Professor E. Scacchi made another sacrifice: he gave us about one gram and a half of vesbine mixed with fragments of lava and silicates (essentially sodalite), which represent the last residuum of the material collected with so much care by A. Scacchi. This was for us particularly precious because it consisted of typical vesbine.

The analysis was carried out as follows. The pulverized material was treated with very dilute nitric acid, first in the cold and then slightly warmed for a few minutes. The vesbine dissolved entirely. The insoluble residue (particles of lava and small crystals of pneumatolytic silicates) was weighed.

The solution was evaporated to dryness, thus separating the silica. Then, successively, the lead was precipitated as sulphate, the copper was determined electrolytically, and the molybdenum and arsenic were precipitated by hydrogen sulphide under pressure, and alumina with a little iron were precipitated in the filtrate by ammonium hydroxide. As the aluminum hydroxide was contaminated by vanadium, (as has been noted by others), even after several reprecipitations, this trace of vanadium was determined colorimetrically. Phosphoric pentoxide was determined in the ammonia precipitate, Treadwell's procedure being used.

After the separation of aluminum and iron the vanadium was determined by the use of cupferron, according to the method of Turner.[12] Manganese, cobalt, etc., were precipitated by an excess of ammonium sulphide, and the filtrate was evaporated to dryness. The ammonium salts were driven off and a small amount of vanadium was determined colorimetrically in the acid solution. Calcium and magnesium were searched for, but with negative results. Water, chlorine, and arsenic were determined in three separate portions, the last colorimetrically.

The final results were as follows.

ANALYSIS OF VESBINE

CuO	12.90	0.162		
MnO	0.22	0.003	0.296	4.01*
PbO	29.31	0.131		
V_2O_5	12.90	0.071		
P_2O_5	0.19	0.001	0.073	1.00
As_2O_3	0.20	0.001		
MoO_3	0.47	0.003		
H_2O (over $CaCl_2$)	2.13	0.118		
H_2O (110°)	1.80	0.100	0.550	7.53
H_2O (110°+)	5.98	0.332		
SiO_2	4.68			
Al_2O_3	4.89			
Fe_2O_3	0.24			
Mn_3O_4	0.45			
CaO	none			
MgO	none			
Cl	0.82			
Insoluble	20.07			
	97.25			
O for Cl_2	0.18			
	97.07			
Na_2O (by dif)	2.93			
	100.00			

* CuO+MnO+PbO=0.293; 0.003 being assumed to form with MoO_3 a compound $R''MoO_4$.

Reducing to 100 per cent the constituents referable to vesbine, this mineral would have the following composition:

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[12] W. A. Turner: *Am. Jour. Sci.*, (4), 41, 339, 1916.

CuO	19.52
MnO	0.33
PbO	44.34
V_2O_5	19.52
P_2O_5	0.28
As_2O_5	0.30
MoO_3	0.71
H_2O (total)	15.00
	100.00

According to the analysis, SiO_2, Al_2O_3, Na_2O, and Cl are present in relative amounts scarcely different from those needed to form sodalite. The percentages, referred to the amount of SiO_2 and based on the formula of sodalite, are calculated to be: Al_2O_3 4.0, Na_2O 3.2, Cl 0.9—figures which show that the silicates that contaminate the vesbine are essentially sodalite. Vesbine is, therefore, definitely not a silico-vanadate, as one might suppose, but a simple vanadate. The absence of silica was also shown by microchemical tests on carefully selected particles of vesbine, and the absence of alumina was also proved microchemically.

Vesbine is, thus, certainly a vanadate of lead and copper; lead being replaced in very small amount by elements of the rare earths, while some of the manganese and cobalt are regarded as vicarious with copper. The greater part of the manganese shown in the complete analysis is regarded as derived from hausmannite, which forms brown or blackish crusts contaminating the vesbine, the presence of which is shown by the evolution of chlorine on treatment with hydrochloric acid, the approximate relative amount of Mn_3O_4 having been thus determined.

Some of the total water of vesbine is so very weakly bound that it is rapidly taken up by calcium chloride; another portion is eliminated at 110°; while the remainder (5.98 per cent) is driven off only at a higher temperature. It was impossible to study the course of dehydration because of the lack of sufficient material. The ready elimination of water is in harmony with the apparently amorphous character of vesbine. The mineral is, clearly, one of those the water content of which varies with the water-vapor pressure of the ambient.[13]

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[13] The term "*ambient*" (Italian *ambiente*) is here used instead of "surrounding medium" or "atmosphere," as being shorter, self-explanatory, and etymologically correct. The word is given in the Century and in the Standard dictionaries. It is suggested that "ambient" might well replace the other two terms. "Surrounding medium" is somewhat jargonesque, and the "atmosphere" may not be the air in certain cases. (H. S. W.)

If sufficient $CuO+PbO$ is subtracted to form with the MoO_3 a normal molybdate, $R''MoO_4$, the ratios of the constituents of vesbine are as follows: $R''O : (V, P, As)_2O_5 : H_2O = 4.01 : 1 : 4.55$, or 4 : 1 : 4.5 if only the water driven off above 110° be considered; or 4 : 1 : 7.5 if the total water be considered.

The formula for vesbine, in equilibrium with air at 25°, is, therefore; $(Pb, Cu)_3V_2O_8 \cdot (Pb, Cu)(OH)_2 \cdot 6.5H_2O$. This becomes $(Pb, Cu)_3V_2O_8 \cdot (Pb, Cu)(OH)_2 \cdot 5H_2O$ for vesbine dried over calcium chloride at 25°: and $(Pb, Cu)_3V_2O_8 \cdot (Pb, Cu)(OH)_2 \cdot 3.5 H_2O$ for vesbine partially dehydrated at 110°.

Since the water-content of vesbine varies with the aqueous pressure of the ambient and with the temperature, the values for the molecules of water are of slight importance. It would appear that the most acceptable formula for vesbine is that of the material dried over calcium chloride, namely: $(Pb, Cu)_3V_2O_8 \cdot (Pb, Cu)(OH)_2 \cdot 5H_2O$.

Vesbine is, thus, a hydrated cuprodescloizite, using this name in the sense proposed by Wells;[14] that is to say, a descloizite in which zinc is wholly, or almost wholly, replaced by copper.

Our analysis differs much from that by De Luise. It appears to be probable, from the large amount of chlorine found by him, that De Luise examined a mixture of vesbine with much atacamite (?), this name being given provisionally, following A. Scacchi, to the green incrustations on the lava of 1631.

That our analysis is approximately exact, and that the pure vesbine has a fairly constant composition, is indicated by a study of a small quantity of vesbine detached "by him"[15] from the rock with a stiff brush, which we tried to purify with heavy liquids. Only 0.0655 of a gram of material was thus obtained. This was fused with carbonate and nitrate of sodium, and the mass lixiviated with water, CuO and PbO being determined in the residue. The results were: CuO 12.4 and PbO 25.3 per cent; so that these two oxides show the ratio 1.37 (CuO) : 1.0 (PbO), while the ratio in the principal analysis is 1.24 : 1.00. The agreement may be regarded as satisfactory, when the small amount of material used is considered.

Vesbine, heated in the closed tube, gives off water and becomes brown. Before the blowpipe, mixed with sodium carbonate on charcoal, the mass becomes blue, and finally one obtains small scales of metallic copper and globules of lead. The salt of phosphorus bead is green in the reducing flame. Vesbine dissolves in dilute nitric acid, yielding a characteristic bluish green solution. Under the microscope it appears to be amorphous.

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[14] H. G. Wells: *Am. Jour. Sci.*, (4), 36, 636, 1913.

[15] De Luise (?). (H. S. W.)

ORIGIN

Vesbine was found by A. Scacchi, as has been said, in the lava of 1631, as very thin coatings on the walls of crevices, and De Luise reports having found it in the lava of 1868, but very rarely.[16] It would not be surprising to find it in the lavas of other Vesuvian eruptions, inasmuch as the composition of the lavas of Vesuvius does not appear to have changed much since the eruption of 79 A. D.

Vanadium, however, exists in very small amounts in the lavas of Vesuvius, so that one can understand how vesbine, a vanadate, is found in the lavas of 1631. These, given their great mass, have been able to concentrate, in the exhalations during their cooling, the vanadium needed for the formation of the observed vesbine. One might also assume that the lavas of 1631 were richer in vanadium than later lavas, because the eruption of 1631 took place after a long period of repose, during which the upper part of the magma column, which formed the flows of that eruption, were enriched in volatile exhalations from the lower portions. Indeed, autopneumatolytic minerals are notably much more abundant in the lavas of 1631 than in those of other eruptions. On the other hand, the exhalations from the Vesuvian magma, which are fairly uniform on the whole, sometimes give evidence of the presence of elements that are not usually found or which occur only in very small amount. Such is the case, for example, with caesium, which has been recently observed by one of us, with Dr. L. Coniglio, in considerable quantity.

It might be thought, in view of its occurrence only on the walls of crevices in the lava, that vesbine is a direct product of autopneumatolysis, such as are some silicates (sodalite, feldspars, mica, etc.) and oxides (hematite, magnetite, and cuprite), which likewise coat the same walls. Vesbine appears, in every case, to be clearly of later formation than these minerals, since it covers and incrusts them cleanly. There are specimens which might lead one to think that the vesbine is a pneumatolytic product, especially those in which the vesbine itself adheres closely to the rock, forming on it thin films, impossible to dislodge. In some cases these are not uniform, but constitute small rosettes, more or less elongated, or they are closely appressed; so that one might think them to be lichens.

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[16] I have observed the films, as a great rarity, in lavas of 1631. (H. S. W.)

On the examination of many specimens, however, as, indeed, is obvious from the presence of water easily driven off at a low temperature, it is clear that vesbine was not formed by gas reactions at a high temperature, but that it is to be considered, on the contrary, as the product of solutions that began after the cooling of the mass of lava, which would, thus, in some respects, correspond to the formation of zeolites in other eruptive rocks. Many of the specimens preserved in the Mineralogical Museum of Naples are very instructive in this respect, and they show clearly that the vesbine and the material of the other colored incrustations of the lava of 1631 formed a sort of mud, which ran over the walls of the crevices of this lava.[17]

According to our observations, we think that vesbine has been formed thus. Among the products of the exhalations of the lava of the eruption of 1631 there were alkaline vanadates. Water, which was certainly present during the cooling and solidification of the lava, dissolved these and thus made them capable of reacting with the [traces of] lead and copper present in the magma. Thus there came about the existence of vesbine, which in one place was immediately deposited, and elsewhere was carried to varying distances, to form on the walls of the crevices the crusts that have been described.

CONCLUSIONS

1. The identity of vesbium with vanadium has been definitively shown, by spectroscopic and chemical methods.

2. Vesbine has a composition corresponding to that of a hydrated cuprodescloizite, which is best represented by the formula $(Pb, Cu)_3V_2O_8 \cdot (Pb, Cu)(OH)_2 \cdot 5H_2O$. The amount of water, however, varies with the water-vapor pressure of the ambient.

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[17] In the original paper several photographs are given, which show various modes of occurrence of vesbine, but which it is not necessary to reproduce here. (H. S. W.)

3. It has been established, by spectroscopic methods, that in vesbine lead is replaced, to a very small extent, by metals of the rare earths, among which have been certainly recognized La, Ce, Nd, Y, and Er, and Dy doubtfully. This is the first time that the rare earth elements have been detected in Vesuvian lavas. The same may be said of tungsten, which was also noted spectroscopically; it probably replaces molybdenum. There are doubtful spectroscopic indications of the presence of columbium and of tantalum, neither of which have heretofore been noted at Vesuvius. Arsenic, also found by us as the orthoarsenate in vesbine, is new for the Vesuvian fumaroles.

4. It is shown that vesbine is not an autopneumatolytic product, but that it was formed at a period after the solidification of the lava, through the agency of water.

NOTES ON THE TRICLINIC PYROXENES

A. N. Winchell, *University of Wisconsin.*

The standard treatises on mineralogy all refer rhodonite, bustamite, fowlerite and babingtonite to the triclinic pyroxenes, but show no agreement at all regarding the other members of the group. Dana[1] includes hiortdahlite in the group, but it is excluded by others because it is not a metasilicate; Hintze[2] includes jadeite as a triclinic pyroxene, but other authors agree that it is monoclinic; Groth[3] adds schizolite and margarosanite to the triclinic pyroxenes, but their crystallographic angles and constants differ decidedly from those of any pyroxenes. Washington and Merwin[4] add sobralite, pyroxmangite and vogtite to this triclinic group of minerals, but suggest that the group should not be regarded as pyroxenes.

Every mineralogist understands that mineral formulas are practically always simplified too much to represent accurately the real composition. Such simplification is highly desirable so long as no elements which are necessary to the mineral are excluded from the formula. For example, it is proper to consider that ZnS is the formula of sphalerite since the iron, usually present, is entirely unnecessary and merely proxies for part of the zinc. Similarly, it is correct to state that $NaAlSiO_4$ is the formula of nephelite since other constituents (including excess SiO_2) are quite unnecessary to the mineral.

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[1] *System of Mineralogy,* 1892, p. 344.
[2] *Handbuch der Mineralogie,* II, 1897, p. 960.
[3] *Mineralogische Tabellen,* 1921, p. 88 and 108.
[4] *Am. Mineral.,* VIII, 1923, p. 215.

With these facts in mind what formulas should be assigned to rhodonite and babingtonite? According to all authorities the formula of rhodonite is $MnSiO_3$; according to Miers[5] that of babingtonite is $FeSiO_3$. Analyses show that $MnSiO_3$ forms about 85 molecular percent of rhodonite and $FeSiO_3$ forms only about 15–20 percent of babingtonite. Since $FeSiO_3$ forms such a small portion of babingtonite it is not surprising that other writers do not agree with Miers in the view that the simplified formula of babingtonite is $FeSiO_3$; but the case is interesting as illustrating to what lengths this process of simplification of formulas is sometimes carried in our text books. It is the prevailing view that the formula of babingtonite must be more complicated than $FeSiO_3$, but there is no agreement concerning it. Rammelsberg[6] regarded it as composed of $(Ca, Fe, Mn)SiO_3$ and $Fe_2(SiO_3)_3$. Doelter[7] explained it as composed of $Ca(Fe, Mn)Si_2O_6$, $CaFe_2Si_4O_{12}$ and $CaSiO_3$. Silvia Hillebrand[8] regarded it as a mixture of $Ca_2Si_3O_8$ and $CaFe_2Si_2O_8$. More recently Washington and Merwin[9] have concluded that it is a mixture of $Ca(Fe, Mn)Si_2O_6$, $\overset{\prime\prime}{Fe}\overset{\prime\prime\prime}{Fe}_2Si_4O_{12}$, $CaSiO_3$, and $H_2CaSi_2O_6$. It seems possible that the correct explanation of the composition of babingtonite is still undiscovered.

In regard to rhodonite, the simplification involved in considering that it is $MnSiO_3$ is no greater than that involved in deriving many mineral formulas. However, the fact that the simplification is not greater than in many other cases does not prove that it is permissible in this case. That depends upon whether the constituents omitted from the formula are necessary or unnecessary to the mineral. In other words, it depends upon whether the mineral rhodonite is essentially the same as, or essentially different from, pure crystallized $MnSiO_3$. Kallenberg[10] has investigated this matter with the following results:

1. Natural rhodonite is negative and biaxial of large optic angle.

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[5] *Mineralogy*, London, **1902**, p. 424.
[6] *Handbuch der Mineralchemie*, **II**, 1875, p. 404.
[7] *Tsch. Min. Pet. Mitt.*, **II**, 1880, p. 198.
[8] *Tsch. Min. Pet. Mitt.*, **XXXII**, 1914, p. 264.
[9] *Am. Mineral.*, **VIII**, 1923, p. 215.
[10] *Centr. Mineral.*, **1914**, p. 388.

2. Natural rhodonite, when fused and recrystallized, is negative and biaxial of large optic angle.

3. Artificial $MnSiO_3$ crystals are positive and biaxial of small optic angle.

4. Crystallization of artificial $MnSiO_3$ at lower temperatures with fluxes does not change the optic sign.

5. The addition to $MnSiO_3$ of small percentages of $FeSiO_3$ (similar to the tenor of $FeSiO_3$ in some natural rhodonites) does not change the optic sign to negative, but this result is obtained by adding 30–40 per cent of $FeSiO_3$.

6. The addition to $MnSiO_3$ of $MgSiO_3$ does not change the sign.

7. The addition to $MnSiO_3$ of 5 percent (or more) of $CaSiO_3$ changes the substance to negative and biaxial.

Kallenberg supposed that $MnSiO_3$ and $CaSiO_3$ form an isomorphous or isodimorphous series, but his evidence on this point is not conclusive; in fact, his fusing point curve may well pertain to a pair of substances miscible as liquids, but showing little or no solubility as crystals; and one or more intermediate compounds are quite possible, especially if they are unstable at their melting points.

The writer would therefore reinterpret the evidence supplied by Kallenberg to mean that:

1. Natural rhodonite is essentially different from pure $MnSiO_3$. This difference is not due to inversion, nor is it due to admixed $FeSiO_3$ or $MgSiO_3$.

2. Natural rhodonite is essentially the same as $MnSiO_3$ *with some* $CaSiO_3$. Therefore Ca can not correctly be omitted from the formula of rhodonite.

A brief study of the analyses of rhodonite shows that calcium is always present and does not vary very radically in tenor. The best analyses may be represented fairly well by writing the formula as $CaMn_5(SiO_3)_6$. It seems clear from the analyses of rhodonite (excluding bustamite which is probably a separate species and not a variety) that more Ca than is expressed by this formula is not possible in this mineral; this conclusion is supported by the observation of Hallimond[11] that slags containing more than about 8% CaO crystallize to vogtite and not to rhodonite.

If rhodonite is a mineral whose formula expresses a definite ratio between Ca and Mn then what is to be said regarding other ratios? Are any other ratios known among minerals?

[11] *Mineral. Mag.*, **XVIII**, 1919, p. 368.

It seems possible that pyroxmangite[12] represents the essentially calcium free[13] substance, though it contains much iron. Ford and Bradley very properly emphasized the fact that pyroxmangite is not the same as, nor a variety of, rhodonite in their original description of the mineral. It is positive and biaxial of rather small optic angle.

Sobralite[14] is complex in composition; it has been assigned the formula: $CaMgFe_2Mn_4(SiO_3)_8$. Since some analyses of rhodonite suggest that considerable $MnMn_5(SiO_3)_6$ is miscible in crystal solution in $CaMn_5(SiO_3)_6$ it might be supposed that sobralite represents such an isomorphous member of a rhodonite system, but, since sobralite differs optically and also in its X-ray pattern[15] from rhodonite, such a conclusion is not warranted.

Fowlerite[16] has about the same tenor of Ca as rhodonite and may be regarded as $Ca(Mn,Fe,Zn)_5\,(SiO_3)_6$. The optic sign of fowlerite is different from that of rhodonite, but this may well be due to variation through 90° with increase of zinc, since the dispersion is also different.

Bustamite[17] has much more Ca than rhodonite and seems to be essentially $CaMnSi_2O_6$. The best analyses show little evidence of the existence of a gradation between rhodonite and bustamite. In crystallography, also, bustamite seems to differ distinctly from rhodonite.

Vogtite[18] is a substance found in slags which is similar to bustamite in optic orientation but seems to differ both from bustamite and rhodonite in composition since the formula is $Ca(Fe, Mn, Mg)_2Si_3O_9$. Hallimond[18] in the original description showed that vogtite differs in essential characters from rhodonite, and it seems probable that it is also essentially different both in composition and properties (notably the cleavages) from bustamite.

In summary, there is a group of triclinic minerals usually (but incorrectly?) referred to the pyroxene group whose formulas and mutual relationships are still uncertain. This group consists of metasilicates of manganese[19] and calcium in which the ratio between manganese and calcium seems to vary from 1 : 0 to 1 : 1. However, these minerals differ too much optically and crystallographically[20] to belong to an isomorphous series in the narrow sense of that term. The chief types thus far known are the following:

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[12] W. E. Ford and W. M. Bradley: *Am. Jour. Sci.*, **CLXXXVI**, 1913, p. 169.

[13] This assumes that the CaO actually found (1.88%) is negligible because it is not essential.

[14] J. Palmgren: *Bull. Geol. Inst. Univ. Upsala*, **XIV**, 1917, p. 109 and J. M. Sobral: *Bull. Geol. Inst. Univ. Upsala*, **XVIII**, 1922, p. 47.

[15] Wyckoff, Merwin and Washington: *Am. Jour. Sci.* **CCX**, 1925, p. 383.

[16] E. S. Larsen and E. V. Shannon: *Am. Mineral.* **VII**, 1922, p. 95 and 149.

[17] E. S. Larsen and E. V. Shannon: *Am. Mineral.* **VII**, 1922, p. 95.

[18] A. F. Hallimond: *Mineral. Mag.* **XVIII**, 1919, p. 368.

MINERAL	FORMULA	RATIO OF Ca TO Mn(+Fe+Mg)
Pyroxmangite	$(Fe, Mn)SiO_3$	1 to ∞ or 0 to 1
Sobralite	$CaMgFe_2Mn_4(SiO_3)_8$	1 to 7
Rhodonite	$CaMn_5(SiO_3)_6$	1 to 5
Fowlerite	$Ca(Mn, Fe, Zn)_5 (SiO_3)_6$	1 to 5
Vogtite	$Ca(Mn, Fe, Mg)_2 (SiO_3)_3$	1 to 2
Bustamite	$CaMn(SiO_3)_2$	1 to 1

Babingtonite probably belongs to this group, but its formula is still under discussion.

THE MINERALS OF VESUVIUS[1]

ALBERT PELLOUX, *University of Genoa.*

The minerals that occur about Vesuvius, which now number more than one hundred and fifty species, may be arranged genetically into four groups:

I. Minerals that are found in the ejected limestone blocks of Monte Somma.[2]

II. Pneumatolytic minerals formed in cavities of leucotephrites and conglomeratic blocks ejected by Monte Somma and Vesuvius, or coating the walls of ancient lavas.

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[19] With or without iron and magnesium.

[20] As proved especially by their X-ray patterns: see *Am. Jour. Sci.*, **CCX**, 1925, p. 383.

[1] In the preparation of this paper, I have consulted and taken considerable data from the following important works on Vesuvian minerals:

A. Scacchi. Catalogo dei minerali vesuviani con notizie della loro composizione e giacimento Napoli, 1887.

ibid. Catalogo dei minerali e delle rocce vesuviane. (*Atti della R. Academiac delle scienze fisiche e matematiche di Napoli,* Vol. I, 4 Series) Napoli, 1889.

A. Lacroix. Etude minéralogique des produits silicates de l'eruption du Vésuve (avril 1906). (*Nouvelles archives du Muséum,* 4 series. Vol. IX) Paris, 1907.

ibid. Les minéraux des fumerolles de l'eruption du Vésuve en avail 1906. (*Bulletin de la Société fançaise de minéralogie*), Paris 1908.

F. Zambonini. Mineralogia vesuviana. (*Atti della R Accademia delle scienze fisiche e matematiche di Napoli,* Vol. XIV Series 2, no. 7) Napoli, 1912.

F. Zambonini. Appendice alla Mineralogia vesuviana (*Atti Reale Accad. delle scienze di Napoli,* Vol. XV series 2, no. 12) Napoli, 1912.

Notices of new vesuvian minerals are reported in the publication: *Annali dell' Osservatorio vesuviano* (terza serie a cura del comitate vulcanologico di Napoli) of which the first vol. (1924) has been issued.

[2] Monte Somma is the name of an ancient crater wall which forms a semicircular cliff to the north and east of the modern cone. In views of Naples it is seen as a ridge to the left of the present cone.

III. Fumarolic products.

IV. Minerals that occur as rock constituents of Vesuvius and Monte Somma.

I. MINERALS IN EJECTED LIMESTONE BLOCKS

The blocks that are mentioned in the first group occur scattered in the tuffs of which Monte Somma is largely built, and may be easily collected in the ravines of the volcano, especially after long periods of rain. These limestone blocks are in various stages of metamorphism, from blocks that are intact or only calcined, to those in which the original limestone has been entirely replaced by aggregates of silicate minerals. Some of the blocks show geodes in which are found the finest crystallized specimens of Vesuvian minerals; others, however, form compact masses. In this paper the common minerals are indicated by the letter (c), rare minerals by (r) and very rare minerals by (vr).

The minerals occurring in ejected limestone blocks are as follows:

GRAPHITE: small masses with fluorite (vr). MOLYBDENITE? scales and fine granular masses in galena. GALENA: lamellar or granular masses with sphalerite, seldom with pyrrhotite and molybdenite. SPHALERITE: usually lamellar, rarely in crystals; very ferriferous. PYRRHOTITE: tabular crystals (r). CHALCOPYRITE: in small masses. PYRITE: very small crystals. FLUORITE: colorless crystals in geodes (r). PERICLASE: small pale green crystals with forsterite (r). MASSICOT: yellow coatings on galena (vr). HEMATITE (c). MAGNETITE (c). SPINEL: (pleonaste), black, or dark green crystals with humite, mica, forsterite, pyroxene (c). Ruby spinel was found in a marble of Monte Somma, while chlorspinel was observed in some blocks with humite (vr). LIMONITE: occurs as an alteration product of iron minerals. CALCITE: (c). DOLOMITE. SIDERITE: in small crystals with dolomite (r). MAGNESITE (?) earthy. ARAGONITE: crystals in geodes (r). HYDROZINCITE: white crusts on sphalerite, as an alteration product (r). ORTHOCLASE, SANIDINE: (c). ANORTHITE: fine crystals with meionite and leucite. LEUCITE: in geodes with meionite, augite, and rarely davyne, microsommite, and humite. DIOPSIDE: yellow crystals with mica, humite, garnet, and magnetite; white and green crystals with mica, vesuvianite, garnet, and augite. AUGITE: dark green to black. WOLLASTONITE: rarely in good crystals, or lamellar masses. AMPHIBOLE. NEPHELITE: in geodes with mica, humite, vesuvianite. KALIOPHILITE: colorless crystals in geodes with mica and augite (r). DAVYNE-MICROSOMMITE: colorless crystals with garnet, vesuvianite, and sometimes sanidine. NATRODAVYNE: in geodes with garnet, pyroxene, sanidine, amphibole, and vesuvianite. CANCRINITE: in geodes with calcite, mica, nepheline, forsterite, humite, and spinel (vr). CALCIOCANCRINITE? SODALITE: colorless, white or greenish crystals with garnet, vesuvianite, mica, augite, and rarely leucite; rarely in meionite geodes. MOLYBDOSODALITE: Pale green crystals with humite, vesuvianite, and garnet (r). HAUYNITE: blue, granular, rare. LAPIS-LAZULI: blue masses, with mica (r). GARNET: (grossularite, almandite, andradite, melanite, etc.) with vesuvianite, sodalite, and cuspidine; in geodes, (c MONTICELLITE: colorless or yellowish crystals or grains, with mica, vesuvianite, cuspidine, pleonaste, and green pyroxene (r). FORSTERITE: colorless, white, or gray crystals, in geodes, always associated with pleonaste. OLIVINE: yellowish-green or honey-yellow crystals or grains with pleonaste, pyroxene, and sometimes mica. MEIONITE: colorless crystals (white, when altered), occurring in geodes of the limestone blocks, with leucite and augite, and sometimes anorthite, davyne, garnet, titanite, (r). AKERMANITE: glassy, colorless, massive, with pale blue diopside containing copper (vr). VESUVIANITE: greenish-yellow, olive-green, reddish-brown, dark brown to black; in geodes with garnet, mica, sodalite, pyroxene, amphibole, pleonaste, forsterite, davyne, humite, cuspidine, meionite, etc. (c). CUSPIDINE: white, colorless, or pink, with mica, and some augite. CHONDRODITE, HUMITE, CLINOHUMITE: yellow, red, brown, rarely colorless or white; in geodes or forming the mass of the rock, with pleonaste, forsterite, and olivine. BIOTITE: yellowish, reddish, brownish, or black, crystals in geodes, with humite, pyroxene, and forsterite. TITANITE: pale yellow, in geodes. DYSANALYTE: found in small amounts in two limestone fragments. PEROVSKITE: small black crystals in geodes with spinel, calcite, and apatite, (vr). APATITE: colorless, with sphalerite. ANGLESITE: alteration of galena, (vr).

PERICLASE and hydromagnesite occur in the predazzites and pencatites of Monte Somma.

II. MINERALS IN EJECTED BLOCKS FORMED BY PNEUMATOLYSIS

In the second group, to which are referred the minerals formed by pneumatolytic processes, the crystals occur coating the cavities of the blocks or covering the walls of the lava fissures. Such crystals are generally small, but many are very rare and interesting. The blocks in which the pneumatolytic minerals occur may be found along the slopes of Vesuvius, or are enclosed in some of the lavas. In the latter case they may be collected in the ravines (locally named "cupe"), in the lava cracks, or in the small quarries that have been opened in the ancient lava flows. The Minerals of this group may be listed as follows:

MINERALS IN EJECTED LEUCOTEPHRITE BLOCKS

CHALCOPYRITE: in cavities, (r). PYRITE: small crystals in cavities. HALITE and SYLVITE: excellent crystals were observed in a leucotephrite block ejected in 1906. SELLAITE: occurs only in needles and microscopic crystals in a conglomeratic block that was found enclosed in the lava of 1872; the mineral filled the cavities, and was associated with anhydrite, gypsum, hematite, mica, and wagnerite. CHLORMANGANOKALITE: yellow crystals were found in a leucotephrite block ejected in 1906; it was associated with halite and sylvite. QUARTZ: in crystals in geodes of blocks of Monte Somma (r). TRIDYMITE: observed in cavities associated with wollastonite, augite, aegirite, and titanite, (r). HEMATITE. MAGNETITE. PSEUDOBROOKITE: crystals were found in a block similar to the one which produced sellaite, (vr). CALCITE. DOLOMITE. SIDERITE. ARAGONITE: crystals in geodes. THERMONATRITE: white crusts in cavities of some blocks, associated with trona. SANIDINE. OLIGOCLASE. ANORTHITE: in the blocks containing sellaite. LEUCITE, (c). ENSTATITE: very small reddish crystals in the cavities of a block ejected in 1906; with sanidine, mica, hematite, magnetite, apatite, gypsum, and anhydrite, (vr). AUGITE. WOLLASTONITE, (r). AMPHIBOLE. NEPHELITE. MICROSOMMITE: rare in the leucotephritic blocks of Monte Somma, and very common in those of Vesuvius. SODALITE. HAUYNITE. OLIVINE: in some blocks ejected in 1906, sometimes altered to Iddingsite. FAYALITE: in some blocks ejected in 1906, with magnetite, sanidine, augite, and sodalite, (r). WERNERITE: in blocks containing large leucite crystals. ILVAITE: in the cavities of a 1906 block. PHILLIPSITE; ANALCITE; SCOLECITE; THOMSONITE: these occur in some blocks on Monte Somma. BIOTITE. TITANITE. APATITE: in the block that contained sellaite; fine crystals also were found in a block ejected in 1872. WAGNERITE: small wine-yellow or white crystals covered with a crust of apatite; in the block that showed sellaite. ANHYDRITE. BASSANITE: formerly found with hydrargyllite and gypsum in blocks ejected in 1906. GYPSUM. SYNGENITE: colorless crystals in cavities in a block ejected in 1906, (vr).

MINERALS IN EJECTED SANIDINITE BLOCKS

PYRRHOTITE: tabular crystals in sanidinites of Monte Somma, (r). FLUORITE: colorless crystals in some blocks of Monte Somma, particularly those carrying hiortdahlite and zircon. HEMATITE. MAGNETITE. BADDELEYITE: small pale green to brownish green crystals in a sanidinite of Monte Somma with sanidine, fluorite, zircon, magnetite, and pyrrhite, (vr). SANIDINE: transparent crystals in cavities. AUGITE. HIORTDAHLITE: pale yellow crystals with sanidine, sodalite, amphibole, biotite, melanite, zircon, titanite, and fluorite. AMPHIBOLE. MICROSOMMITE. SODALITE. GARNET. VESUVIANITE, (c). ZIRCON: colorless, pale blue, or violet crystals. ALLANITE: a few black crystals have been found. BIOTITE, (c). TITANITE. PYRRHITE: reddish brown, minute octahedral crystals.

MINERALS IN EJECTED SARCOLITE BLOCKS

The sarcolite rocks occur as ejected blocks, which represent leucitites that have been metamorphosed by absorption of limestone.

WOLLASTONITE, (c). DAVYNE-MICROSOMMITE: large, fine crystals. OLIVINE. SARCOLITE: pale flesh-colored to colorless crystals in geodes, or making up the mass of the rock, (vr). MELILITE. MELANITE. CUSPIDINE, (r). BIOTITE. APATITE.

OTHER EJECTED BLOCKS.

QUARTZ: common in blocks ejected in 1906. AEGIRITE and AEGIRITE-AUGITE: occur as reddish brown crystals in blocks and ashes of various eruptions. MIZZONITE: colorless or white crystals (vr), in geodes of some blocks of nephelite microsyenites, with sodalite, vesuvianite, augite, davyne, and garnet. MELILITE: occurs in blocks with augite, olivine, mica, and pleonaste, and sometimes kaliophilite; some square red crystals of melilite occur in geodes of an ancient lava of Pollena, associated with augite, anorthite, and mica.

III. FUMAROLIC PRODUCTS

The fumarolic minerals occur as a product of direct sublimation, or as a result of the chemical reactions between various emanations. Professor Lacroix has classified the fumaroles as follows:

A. High temperature fumaroles which produce essentially potassium and sodium salts. These correspond to the "Dry Fumaroles" of Saint Clair Deville, and yield also chlorides and sulfates of copper and lead, some sulfides of iron, and several iron and copper oxides.

B. Acid fumaroles which, at a lower temperature, produce iron, magnesium, alumnium, and manganese chlorides, as well as sulfur and realgar.

C. Sal Ammoniac fumaroles which occur especially where the lava flows covered vegetation, giving also a small quantity of ammonium sulfate and fluoride.

D. Sulfurous fumaroles which produce sulfuric acid and abundant steam. To these fumaroles must be referred the occurrence of sulfur, gypsum, sassolite, and sulfates of potassium, aluminum, and iron. Likewise the formation of opal due to the alteration of silicates may be ascribed to these emanations.

Many of the fumarolic products are of great interest, both from the study of the genesis of the minerals, and because of their rarity; a number of species being peculiar to Vesuvius, or even restricted to a single eruption. Unfortunately many of them are subject to rapid alteration, or being quite soluble, are quickly carried off by rains shortly after their formation. The best way to preserve them from alteration consists in sealing them in glass tubes or bottles.

SULFUR:[3] small crystals; also massive, globular, and stalactitic; very abundant. SELENIUM: deep red to pink crusts on the lavas of 1858 and 1859; also observed in fumaroles of 1895 and 1906; was extracted from ashes of 1906; (vr). SILVESTRITE (SIDERAZOT): thin metallic coatings of some lavas, (r). REALGAR: small crystals with sulfur and selenium from various eruptions particularly those of 1822 and 1906, (r). ORPIMENT: from alteration of realgar. GALENA: with pyrite, pyrrhotite, and magnetite, (vr). COVELLITE: thin crusts, produced in 1803, 1907, and 1909, (vr). MILLERITE: observed only once in capillary crystals on Vesuvian scorias, (vr). PYRRHOTITE: 1906, (r). CHALCOPYRITE: thin crusts on lapilli of 1906, (r). PYRITE: with galena, (r). HALITE and SYLVITE: rarely in crystals, commonly as incrustations, earthy or arborescent; occurring together in dry fumaroles. SAL AMMONIAC: very common; present in some ashes and lapilli. HYDROPHILITE? according to Zambonini this deliquescent mineral is probably CHLOROCALCITE, (vr).

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[3] Also observed filling fissures of a marl of Monte Somma.

FLUORITE? in a Pollena lava with vesbine. CHLOROMAGNESITE: a deliquescence on lava, mixed with halite and sylvite (vr). LAWRENCITE?: stalactites found in the crater of 1922 were composed of a ferrous chloride, with halite and salammoniac; according to Zambonini it is probably, partly, RINNEITE, (vr). SCACCHITE: a deliquescence with other chlorides, (vr). MELANOTHALLITE: rapidly altering thin black scales, sublimed on crater walls formed in 1868 and 1906. COTUNNITE: acicular crystals, scales, arborescent aggregates or fused masses; also as pseudomorphs after galena formed in 1906, (r). PSEUDOCOTUNNITE: thin crusts and needles, formed in 1902 and 1906, (vr). MOLYSITE: commonly mixed with other salts; the yellow and red color of the rocks near the crater are due to this altered mineral. CHLORMANGANOKALITE: yellow crystals found in a block of leucotephrite ejected in 1906, (vr). HIERATITE: observed in very small colorless crystals with selenium in 1895, (vr). CRYPTOHALITE: microscopic crystals in some sal ammoniac crusts of 1850 and 1906, (vr.) MATLOCKITE? formed in 1858 and 1872. ATACAMITE: thin green crusts on lavas of 1631 with vesbine and azurite; on some blocks ejected in 1906, (c). HYDROMELANOTHALLITE: a green alteration of melanothallite. ERYTHROCALCITE: pale blue wool-like aggregates formed in 1868, with melanothallite, hydromelanothallite, hydrocyanite, dolerophanite, and euchlorite, (vr). ATELITE: a green alteration of tenorite, (c). KREMERSITE: red crystals of 1851, (vr). ERYTHROSIDERITE: red crystals, very deliquescent, (r). CHLORALLUMINITE: small crystals in some stallactitic crusts, 1906, (vr). OPAL: a sublimate of sulfurous fumaroles. CUPRITE: found only once in dark red-violet microscopic crystals with atacamite on lava of 1631. TENORITE: minute black scales, with halite and sylvite; dry fumaroles, now rare. HEMATITE: crystals encrusting lavas; was very abundant at Fosse Cancherone, a vent of Monte Somma. MAGNETITE. MAGNESIOFERRITE: magnetic iron-gray crystals on the Fosse Cancherone scorias; also in fumaroles of 1855 and probably of 1906 (r). HAUSMANNITE: thin brown coatings of lavas of 1631 and on sodalite crystals. MINIUM: dusty red layers forming cement of a conglomerate near the lava flows of Le Novelle near Resina, in 1912, (vr). SASSOLITE: thin colorless scales as a product of various eruptions; with gypsum and sulfur in fumaroles and with realgar in those of the Atrio del Cavallo in 1909, (r). HYDRARGYLLITE: hexagonal scales with bassanite, (vr). ANTIMONY TRIOXIDE? some crusts on the lavas of 1850, and sublimates of 1872. AZURITE: blue coatings on lavas of 1631. THERMONATRITE: white crusts on lavas, sometimes in stalactites, (r). NATRON: efflorescences in interior of some lavas. GARNIERITE? DESCLOIZITE? (Vesbine): in yellow or greenish crusts coating lavas of 1631; was considered by A. Scacchi to be an aluminum salt of a new element called by him Vesbium; according to Zambonini it may be descloizite. MASCAGNITE: white crystalline crusts mixed with sal ammoniac, sylite, and halite, on the Boscotrecase lavas of 1906. THENARDITE: white crusts on walls of some caves of lava. The mineral formed stalactites 60 cm. in length, with some sylvite and halite, (r). APHTHITALITE: tabular crystals, bladed aggregates, massive, incrusting, stalactitic; white, blue or green; a product of fumaroles which yield potassium and sodium salts. ANGLESITE: small, pale violet crystals; white to greenish crusts; formed in 1868, 1906; and 1907. PALMIERITE: minute hexagonal scales resembling sassolite; a product of dry fumaroles of 1868, 1872, 1906, and 1919; occurs with aphthitalite, (which sometimes encloses it), ferronatrite, jarosite, and euchlorine, (vr). BASSANITE: in some fumaroles on west side of crater formed in 1911. MANGANOLANGBEINITEmicroscopic pink tetrahedrons, in stalactites composed of thenardite, and sodium and potassium chlorides, (vr). HYDROCYANITE: abundant in fumaroles of 1868, with euchlorine, erythrocalcite, melanothallite, and doleropahnite; also in some of 1895; rapidly alters to chalcanthite, (r). EUCHLORINE: grass-green to emerald-green incrustations; tabular crystals; lava of 1868 with hydrocyanite; in fumaroles of the Atrio del Cavallo of 1892–1893; with metavoltine formed in 1906; (c). CHLOROTHIONITE: pale greenish blue to green crusts; 1872 and 1906. DOLEROPHANITE: chestnut to dark brown crystals, 1868, (vr). VERNADSKITE: grass-green aggregates of minute crystals; an alteration product of dolerophanite, (vr). LINARITE: microscopic crystals and grains in gypsum, in some scorias of 1881–1882. MIRABILITE: obtained by solution and recrystallization of salt mixtures found in fumaroles of 1855 and 1906, (vr). EXANTHALITE: white efflorescence on a lava of 1813, (vr). GYPSUM: small white crystals, very common. EPSOMITE: obtained by solution of some crusts, 1850 and 1855, (r). CUPROMAGNESITE: green conglomerates found among the bombs of 1872 were partly soluble in water, and A. Scacchi obtained crystals of this substance, (vr). MELANTERITE? 1822. CHALCANTHITE: a secondary product, (r). PICROMERITE: with cyanochroite; also obtained by solution of salts of 1855 and 1872. CYANOCHROITE: pale blue crusts, (r). KALINITE: white crusts; in the sulfurous fumaroles of the Atrio del Cavallo, (c). ALUNOGEN: mixed with kalinite in products of various eruptions; in 1908 in silky fibrous masses on the Atrio del Cavallo. FERRONATRITE: thin adamantine needles embedded in a mixture of white and blue salts collected in the crater in 1919, with aphthitalite and palmierite; also found in ash nodules in 1913; (vr). VOLTAITE: greenish grains; Atrio del Cavallo, (r). METAVOLTINE: obtained from solution of salts, 1906. Also in yellow crusts and minute crystals with euchlorine. ALUNITE: as a yellow crust in a block ejected in 1906 from the crater; with halite, sylvite, gypsum, and erythrosiderite, (r). JAROSITE: thin crusts of microscopic crystals, found with aphthitalite, euchlorine, and rare chlorides on a scoriaceous lava collected in crater in 1919 (r).

IV. MINERALS OCCURRING AS ROCK CONSTITUENTS

To the fourth group of Vesuvian minerals are referred those species that are the constituents of the various rocks of Monte Somma and Vesuvius. These rocks comprise chiefly leucotephrites, leucitic phonolites, phonolites with large crystals of sanidine, mica trachytes, sanidinites, microsyenites, monzonites, etc. In the cavities of these rocks the constituent minerals occur sometimes well crystallized, and are occasionally associated with minerals produced by pneumatolytic processes. Only a few of these rocks, such as the leucotephrites, form the lava flows and dikes of Vesuvius and Monte Somma; the others are encountered as ejected blocks and are found in tuffs, where they may be collected.

QUARTZ: small masses. OPAL: derived from various silicates under the action of fumarolic gases. LIME: occurs enclosed in some lavas due to the calcining of fragments of limestone. HEMATITE. MAGNETITE: it may be observed in quantity among the sands of the Vesuvian torrents and along the seashore. SANIDINE: very common in Monte Somma rocks; often occurs as transparent crystals in cavities of sanidinite, syenite, sommaite, monzonite, phonolite, and trachyte; sometimes enclosed in large leucite crystals. ANDESINE: occurs in some lavas of 1631; also as a constituent of sanidinite. LABRADORITE: thin tabular crystals in some Vesuvian lavas, and in leucitophyre of Pollena. RIVAITE (a mixture of wollastonite and glass) was found as a small radiated blue nodule. LEUCITE: an essential constituent of the lavas and dikes, as well as of various ejected blocks; the larger crystals occur in leucotephrite. It occurs also in the white pumice of Pompeii. DIOPSIDE: sparingly in sanidinite. AUGITE: abudant in lavas; and in ejected blocks of trachyte, sanidinite, phonolite, monzonite, microsyenite, and sommaite. HIORTDAHLITE: in sodalitic sanidinites of Monte Somma, and in microsyenite. AMPHIBOLES: as constituents of sanidinite, leucitite, phonolite, monzonite, and microsyenite; also in the pumices of Pompeii. NEPHELITE: abundant in the following rocks and their cavities: sodalite sanidinites, sanidinites with garnet, microsyenites with vesuvianite, phonolites with large crystals of sanidine, and micaeous trachyte. SODALITE: a component of various sodalitic rocks of Monte Somma; occurs also in some lavas (1631). HAUYNITE: an accessory constituent of phonolite, mica trachyte, and leucotephrite. GARNETS: in mica syenite, phonolite, and microsyenite. OLIVINE: a constituent of Vesuvius and Monte Somma leucotephrites; occurs also in the lavas of 1631. FAYALITE: dull black tabular crystals in the lavas of 1631, and in some leucotephrite blocks ejected in 1906. WERNERITE: formerly found in large colorless, pale blue or violet crystals in sanidinite blocks. ALLANITE: only found in a very few crystals in a sanidinite. BIOTITE, (c). KAOLINITE: common, as an alteration product of leucite. TITANITE: an accessory constituent of trachyte, phonolite, sanidinite, and microsyenite. LITIDIONITE (neocianite): occurs in some lapilli of 1873. APATITE: an accessory constituent of some lavas and ashes.

A NOTE ON THE OCCURRENCE OF ALASKAITE

W. HORATIO BROWN, *University of Arizona.*

Several summers ago while engaged in professional work in the San Juan region of Colorado, specimens of two uncommon bismuth minerals, lillianite and alaskaite, were collected. Lillianite was identified with ease by means of the tables of Davy and Farnham[1] but alaskaite caused considerable difficulty and it was not until a specimen was obtained from the U. S. National Museum for comparison that it could be positively identified. On account of a cleavage which may be brought out by etching, the appearance of the mineral under the metallurgical microscope is very characteristic.

The alaskaite, which is an argentiferous variety of galenobismuthinite, was found in the Saxon mine, which adjoins the

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[1] Davy, W. M. and Farnham, C. M.: Microscopic Examination of the Ore Minerals, New York, 1920.

Alaska mine where the mineral was discovered by Koenig[2] and from which it is named. These mines are in Poughkeepsie Gulch, in the Silverton Quadrangle, Colorado.

The material from the Alaska mine has been studied by several investigators. Gramont[3] made a spectroscopic examination of the mineral. Liweh[4] classified it as a variety of fahlerz but Koenig[5] disagreed with Liweh because alaskaite carries only a very small amount of antimony. Ransome described the Alaska mine[6] and noted the occurrence of other bismuth minerals in the region.

The mineral occurs as particles usually less than half a centimeter in diameter in vein quartz associated with pyrite. Under the microscope it can be seen that the alaskaite is moulded around euhedral crystals of quartz and pyrite. In places the pyrite is corroded. In polished section corroded areas of sphalerite and tetrahedrite are also visible in the alaskaite and it is cut by minute veinlets of covellite and some dark minerals which may be oxidized lead or copper compounds. Several blade-like areas of chalcopyrite were also found in the polished sections. In the specimen from the Alaska mine, loaned to the writer by the U. S. National Museum, which has a large percentage of chalcopyrite, these rather rectangular blades were much more abundant, so much so that in places the texture was similar to that of a diabasic texture in a rock. Similarily shaped blades of alaskaite were also seen in the chalcopyrite. It is probable that the alaskaite is hypogene and that these intricate intergrowths account for the copper, lead and zinc in Koenig's analyses.

Both the Davy and Farnham etching reactions and blowpipe tests were tried on the specimens. The etching reactions were checked against the specimen loaned to the writer by the U. S. National Museum. The reactions and the physical properties determined are given in the following table.

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[2] Koenig, G. A.: Ueber den Alaskaite, ein neues Glied der Reihe der Wismuthsulfosalze: *Zeit. f. Kryst. u. Min.*, **6**, 42–47 (1882). Also in *Proc. Am. Phil. Soc.*, **19**, p. 472 and **22**, p. 211 (1885).

[3] Gramont, A. de: Directe Spectral Analyse der Mineralien: Abstract in *Zeit. f. Kryst. u. Min.*, **27**, p. 625 (1897).

[4] Liweh, Th.: Fahlerz von Alaska gang im südwestlichen Colorado: *Zeit. f. Kryst. u. Min.*, **10**, p. 488 (1885).

[5] Koenig, G. A.: Ueber Alaskaite: *Zeit. f. Kryst. u. Min.*, **14**, p. 254 (1888).

[6] Ransome, F. L.: Economic Geology of the Silverton Quadrangle, Colo: *U. S. Geol. Survey Bull.* **182**, p. 84 and 195 (1901).

Macroscopic

Color	Silvery or light lead gray.
Luster	Metallic.
Hardness	Two.
Blowpipe	Lead and bismuth reactions on charcoal.
Assay	Ore carrying small proportions assays from 300 to 600 ounces of silver per ton.

Microscopic

HNO_3	Tranishes brown or iridescent, develops cleavage.
HCl	Negative or slight gray tarnish, rubs clean.
KCN	Negative.
$FeCl_3$	Tarnishes brown and develops cleavage.
$HgCl_2$	Negative.
KOH	Tarnishes gray and develops cleavage, may take fifteen minutes to an hour.
Color	In reflected light, galena white.
Optical	In reflected polarized light, slightly anisotropic changing from gray to darker gray.
Cleavage	Two directions.

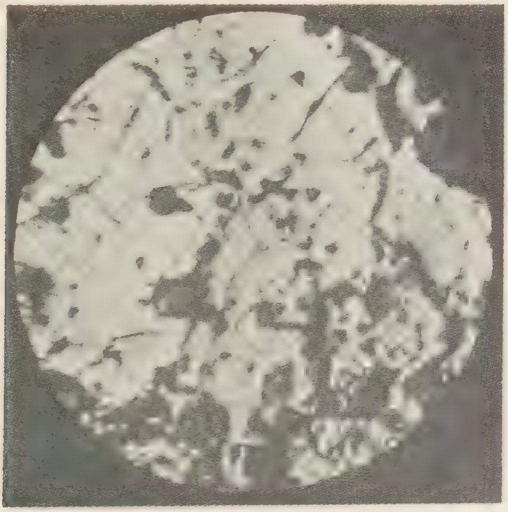

Fig. 1.

Polished section of alaskaite showing cleavages developed by etching.

The accompanying photograph shows the cleavages as brought out by nitric acid. It is believed that the mineral will be found to be fairly abundant in the San Juan region in future studies of the ores as indications of bismuth are frequently encountered in assaying the ores.

KERNITE, A NEW SODIUM BORATE

WALDEMAR T. SCHALLER, *U. S. Geological Survey, Washington D. C.*

The new mineral kernite, $Na_2B_4O_7 \cdot 4H_2O$, was received through Hoyt S. Gale of Los Angeles, California, and is reported to occur in quantity in the southeast corner of Kern County, California, in the Kramer boron district. The name kernite is proposed after the county name. The exact locality is about 4 miles north of Rich, a station on the Santa Fe R. R. and about 25 miles directly east of Mojave, being in Sec. 22, T. 11 N., R. 8W. The mineral was discovered in exploratory borings at a depth of several hundred feet. Ulexite and possibly colemanite are associated minerals. The geology of this field has been described by Gale[1] and Noble.[2]

The writer has a cleavage piece of kernite 2 by 2–1/2 by 6 inches. Apparently single crystals are of large size though no terminated crystals have so far been seen. The mineral is colorless to white, transparent, vitreous to pearly in luster, and greatly resembles some specimens of massive cleavable selenite. Orthorhombic. Perfect prismatic cleavage, $m \wedge m = 71° \ 08'$. Readily breaks into long thin fibers and laths. H = about 3. Sp. Gr. = 1.953. Optically probably negative, although 2V is nearly 90° and sign uncertain. Elongation (c axis) positive. Axial plane is parallel to elongation. $\alpha = 1.454$, $\beta = 1.472$, $\gamma = 1.488$. Before the blowpipe it swells considerably and finally fuses to a clear glass. Very slowly soluble in cold water, the clear cleavage pieces first becoming opaque white due to abundant etch figures.

Analysis of fragments of clear transparent selected material gave the following results, an analysis of the associated massive fibrous ulexite being added.

	Kernite		Ulexite	
	Analysis	Calculated	Analysis	Calculated
Na_2O	22.63	22.66	7.09	7.65
CaO	0	0	14.06	13.85
B_2O_3	50.76	51.02	42.94	42.95
H_2O	26.50	26.32	35.54	35.55
Insol.	0	0	0.10	0
	99.89	100.00	99.73	100.00

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[1] Gale, H. S.; Borate deposits near Kramer, California: *Trans. Amer. Inst. Mining Met. Eng.*, **73,** pp. 449–463 (1926).

[2] Noble, L. F.; Borate deposits in the Kramer district, Kern County, California: *U. S. Geol. Survey Bull.* **785-C,** pp. 45–61 (1926).

The ratios of the analysis of kernite are: $Na_2O:B_2O_3:H_2O = 365 : 729 : 1472$ or $1.00 : 1.99 : 4.02$, the formula for kernite being $Na_2O \cdot 2B_2O_3 \cdot 4H_2O$. Not quite half the water is readily given off at 110° and only three-quarters of the total water is lost up to 200°, there being no swelling of the mineral at this temperature.

The relationships of the water content and physical and optical properties of kernite and the other hydrates of $Na_2O \cdot 2B_2O_3$ (borax and "octahedral" borax, the 5-hydrate) are being studied. Crystallization of a water solution of kernite yields 1.39 times as much borax.

NOTES AND NEWS

THE CRYSTAL STRUCTURE OF SILVER SULFIDE

L. S. Ramsdell, *University of Michigan.*

X-ray data indicate that at ordinary temperatures the two minerals argentite and acanthite, both with the composition Ag_2S and supposedly dimorphous, have identical structures,[1] which are probably orthorhombic. Ag_2S has an inversion point at about 180°C., and a recent experiment[2] indicates that above this temperature the substance gives a cubic diffraction pattern. The described pattern appears to agree with a body-centered cubic structure, and it is assumed, therefore, that the heavier Ag atoms occupy positions at the corners and center of the unit cube. Because of their relatively slight diffraction effects the positions of the lighter S atoms could not be determined. The length of the unit cube is given as 4.84 A. U., and the calculated density is 7.2 (Dana 7.2–7.3)

It is evident from an examination of the data that this structure cannot be correct. The coordinates of the two Ag atoms would be 000 and $\frac{1}{2}\frac{1}{2}\frac{1}{2}$, and the one S atom would be in some other position. But due to the symmetry the only possible points where a single atom could be located in a cube are either 000 or $\frac{1}{2}\frac{1}{2}\frac{1}{2}$. Since these positions are already occupied by Ag atoms, the structure is impossible. In addition to this, if the density is 7.2, a cube of the dimensions stated must contain two molecules of Ag_2S, or four atoms of Ag and two of S, and some arrangement other than a body-centered cube would be necessary to provide the necessary number of positions for the Ag.

The comparatively meagre data (only four lines were measured in the pattern) are hardly sufficient for a satisfactory proof of the structure, but there are indirect means of determining at least a probable structure. Although Cu_2S is orthorhombic at ordinary temperatures, Cu_2Se is cubic, and could reasonably be supposed to be isomorphous with the cubic form of Ag_2S. Davey has shown that Cu_2Se has the CaF_2 type of structure,[3] which requires four molecules in the unit cube.

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[1] Ramsdell, L. S.: Crystal structure of metallic sulfides. *Am. Mineral.*, **10**, 286 (1925).

[2] Emmons, R. C., Stockwell, C. H., and Jones, R. H. B.: Argentite and acanthite. *Am. Mineral.*, **11**, 326 (1926).

[3] *Phys. Rev.*, **21**, 380 (1923).

Assuming this structure to be the correct one for Ag_2S, there would be four atoms with a face-centered cubic arrangement, but they would be too light to materially affect the pattern. The eight Ag atoms would be located at the centers of the eight small cubes made by dividing the unit cell by the three principal planes of symmetry. These heavier Ag atoms by themselves possess a simple cubic arrangement, with the side of the cube one-half that of the true unit cell. The four lines of the diffraction pattern fit this simple cubic structure equally as well as they do the body-centered cube, with a value of 3.40 A. U. for the side of the small cube, or 6.80 A. U. for the side of the true unit cell.

However, a cube of this size, containing four molecules, gives a calculated density of about 5.2, as compared with 7.2 for Ag_2S at room temperatures. There is no justification for using the value of 7.2 as the density of the cubic form, for not only would there be some decrease in density with the increased temperature, but there would probably be a greater change due to the structural inversion. However, this change from 7.2 to 5.2 does seem abnormally large. The writer made several attempts to determine the density of Ag_2S above 180°C by a modified pycnometer method. The results did not check very closely, but all indicated a considerable decrease in density, with an average of about 6. Until a better determination of the density at 180°C can be made, there can be no direct proof of any structure.

The relative intensities of the four lines of the pattern are estimated to be 3, 10, 6, and 2, while the calculated intensities for this CaF_2 type of structure are 5.5, 10, 2, and 2. With the exception of the third line, this is an excellent agreement. Intensities have been calculated for the Cu_2O and FeS_2 types of structure (both of which have the same number of atoms in the molecule as Ag_2S) and for a cube-centered arrangement of Ag atoms, and none are in agreement. For example, the Cu_2O type would have two intense lines from planes 111 and 311, in addition to the four actually present, while with a body-centered type the first line would be four times, and the third line two times as intense as the second line. Accordingly, if the CaF_2 type is not correct, then Ag_2S must possess a structural arrangement different from anything yet found for a compound of the type R_2X.

Since Ag_2S does exist in a cubic form, it has been suggested[4] that argentite and acanthite represent distinct mineral species. Both names are so well established that it may be desirable to retain them, but it should be pointed out that although it is possible to consider Ag_2S above 180°C as a separate mineral to which the name argentite is to be applied, this is of theoretical interest only. The practical conclusion to be drawn is that all specimens which are labelled "argentite" are in reality acanthite, paramorphs after argentite.

ARTIFICIAL FLUORITE

DONALD C. STOCKBARGER, *Rogers Laboratory of Physics. Massachusetts Institute of Technology.*

The value of fluorite having high transparency to ultraviolet radiation of short wave lengths is great enough to warrant an attempt to produce it in the laboratory. To this end the writer and his students have made several trials by fusing chemically pure calcium fluoride in an electric furnace.

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[4] Emmons, Stockwell, and Jones: *Am. Mineral.*, **11**, 326 (1926).

The first experiments, performed in 1922 by G. E. Dean and R. D. Stuart showed that whereas clear melts were readily obtained, the solidified mass was opaque. The problem was attacked anew last year by C. S. Draper, who succeeded in proving that the opacity was due in part to numerous small crystals. These crystals could be made to grow by slow cooling through the freezing point and below, until they were of the order of magnitude of one sixteenth of an inch across. No tests with ultraviolet radiation have been made, but in visible light they appeared to be perfectly transparent. They adhered strongly and the entire mass possessed the cleavage planes characteristic of natural fluorite.

The work is being carried on by M. W. Fort, a graduate student, and the successful growth of large, clear crystals is predicted.

REVIEWS

DIE METALLOGENETISCHEN EPOCHEN UND GEBIETEN

VON SIBIRIEN. W. A. Obrutschew, Abhandlungen zur Praktischen Geologie und Bergwirtschaftslehre, vol. 6. *Berlin,* **1926.** Published by Wilhelm Knapp, Halle (Saale). 63 pages. Price R. M. 5.50

It is a rather difficult task to present an adequate review of this interesting article as the author lists one hundred and thirty-six references from which he has drawn his material and then attempted to condense it into fifty-five pages.

After a short introduction an historical sketch is given covering the main points on the geology of Siberia. A rather detailed discussion follows dealing with the metallogenetic periods and metallogenetic epochs of Siberia. This portion comprises the major part of the article. The classification used is that based on the author's own classification of ore deposits, which was reviewed in *Am. Mineral.*, Vol. **11,** p. 190, 1926. The discussion closes with a short review of the older literature and a general summary of results.

This contribution should prove interesting to readers who wish to acquaint themselves with the mineral wealth of Siberia, but the vast accumulation of data and confusing geographic names make the reading somewhat difficult. A map of Siberia indicating the principal ore deposits accompanies the article. This map together with the comprehensive list of references contribute much to the value of the paper. Tj. L. Reitsema.

ENTWICKLUNGSGESCHICHTE DER MINERALOGISCHEN

WISSENSCHAFTEN. P. Groth. VI+266 pages. Julius Springer. *Berlin,* **1926.**

It is indeed fitting that the eminent teacher and investigator, Professor P. Groth, for many years Director of the Mineralogical Laboratory of the University of Munich and also the founder and first editor of the Zeitschrift fuer Krystallographie und Mineralogie, should bring together the salient facts concerning the development of the mineralogical sciences from the very beginning down to the end of the nineteenth century.

The evolution of our knowledge of the geometrical, physical, and chemical properties of crystals is discussed in Part I. This survey is very timely, especially in view of the recent important developments in these fields which were made possible through the application of x-rays, and which were not dreamed of twenty-five years ago. Some of the subjects treated in this portion of the book are: observation of the constancy of interfacial angles and the description of crystal forms; investigation of the physical properties and the structure of crystals; introduction of crystal axes and the gradual development of the fundamental laws of geometrical crystallography; recognition of the relationships between the geometrical development of form and the optical properties of crystals; and the symmetry of crystals and the theory of crystal structure.

Part II is devoted to what may be termed the recognition of minerals. Here the description, classification, and nomenclature of minerals, as well as the history of important mineral collections and laboratories are considered. There are also chapters on the paragenesis of minerals, ore deposits, composition of minerals, decomposition of minerals, and formation of minerals in nature and by artificial means in the laboratory.

The concluding chapter contains very useful short biographical sketches of thirty-seven outstanding contributors to the mineralogical sciences among whom we are pleased to note three Americans, Genth, Brush, and Penfield.

The volume is a splendid testimonial to the energy and perseverance of one of out eminent mineralogists who, although eithty-three years of age and with greatly impaired eyesight, has been able to complete this splendid contribution to our science. EDWARD H. KRAUS.

THE LAWS OF CHEMICAL CRYSTALLOGRAPHY[1]

An unusually interesting article on the significance of atomic dimensions in crystal structure, isomorphism, etc., has recently been published by Professor V. M. Goldschmidt of the Mineralogical Institute of the University of Oslo (formerly Kristiania), Norway, and a review of the important points brought out may be of interest to readers of the American Mineralogist to whom the original paper is not accesible. His thirteen principal theorems (*Sätze*) are here translated in full.

1. The crystal structure of a substance is conditioned by the size and deformability (*Polarisierbarkeit*) of its components; the latter term comprises atoms or their ions and atomic groups.

A. LAWS CONCERNING SIZE OF CRYSTAL COMPONENTS (*Krystallbausteine*)

Crystals are regarded as made up of spherical or ellipsoidal domains, in contact with one another, which are characterized by their radii, or the distances from their centers to the contact-points.

2. The radius of a crystal-component is conditioned by the atomic number and the state of the atom concerned.

The changes of radius with atomic number and with state of ionization are shown in the following tabulation:

Li^+ 0.78	Na^+ 0.98	K^+ 1.33	Rb^+ 1.49	Cs^+ 1.65	Pb^{++++} 0.84	Pb^{++} 1.32	Pb° 1.74
	Mg^{++} 0.78	Ca^{++} 1.06	Sr^{++} 1.27	Ba^{++} 1.43	Te^{++++} 0.89	Te° 1.43	Te^{--} 2.03
	F^- 1.33	Cl^- 1.81	Br^- 1.96	I^- 2.20			
	O^{--} 1.32	S^{--} 1.74	Se^{--} 1.91	Te^{--} 2.03			

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[1] Review of Professor V. M. Goldschmidt's work, Die Gesetze der Krystalochemie, *Natururssenschaften*, 21, 477–485, May 21, 1926.

3. The radius lengthens with increasing negative charge, and shortens with increasing positive charge. The lengthening of the radius of the atom itself (not the domain) with increasing negative charge is to a certain extent compensated by increasing Coulomb attraction between the components, while on the other hand the shortening of the radius of the atom itself with increased positive change is intensified by the increased Coulomb attraction.

4. In crystal-components of like order and like state the radius is approximately constant. When however the states are dissimilar the radii may be markedly different.

The principal change in the state of an atom concerns its degree of ionization.

5. There are a finite number of mutually incommensurable groups of space-lattice-types, each group characterized by a like state of one or more of the crystal-components.

It is noteworthy that crystals of the sphalerite, wurtzite, and cuprite space-lattice-types are commensurable with those of most of the free elements, and apparently contain atoms in non-ionized condition. In addition to being conditioned by order and state, the radii are more or less influenced by the arrangement and nature of surrounding atoms, as well as by the thermodynamic factors concerned in thermal expansion and compressibility.

B. LAWS CONCERNING DEFORMABILITY OF CRYSTAL-COMPONENTS.

1. Deformability

The deformability of a single crystal-component is primarily dependent on its radius and its charge. The deformability increases with increasing radius, and on the other hand decreases with increasing positive charge. The influence on degree of deformation due to neighboring-components depends on their arrangement and their character. The more symmetrically they are arranged, the less their deforming effect. Moreover, some of them are weakly, others strongly, deforming, their influence being heightened by increased charge, lessened by increased radius.

6. When a deformable crystal-component comes into contact with a deforming crystal-component, the distance between their centers (the sum of their radii) becomes less than the sum of the radii they normally exhibit.

The diminution in interatomic distance may be very marked as in radicles such as nitrate-ion, carbonate-ion, sulfate-ion, etc.

B. 2. Counter-deformability. (*Kontrapolarisation*).

7. Composite crystal-components can become more or less extended in space by the influence of neighboring strongly deforming components, and this phenomenon is termed counter-deformability; in the limiting case, this effect leads to the complete disruption of the radicle, and in extreme cases it may result in developing a new radicle, made up of the deforming component together with the portion of the original radicle which splits off.

The extreme case is illustrated by the spinel group, in which the strong deforming effect of the Mg leads to the splitting up of the aluminate radicle (Al_2O_4) with the formation of the new radicle MgO_4.

C. LAWS CONCERNING ISOMORPHISM.

1. Ordinary Isomorphism

8. Isomorphism between two substances occurs when the relative sizes of the crystal-components and their relative degrees of deformability are equal, within certain limits, or correspond, provided that the empirical chemical formulas of the two substances and also the signs of their electric charges are analogous.

The structures of the members of a number of isomorphous series have been studied by means of X-rays by Goldschmidt and his associates, and it has been found possible to express the limits of dimensions and deformabilities of crystal-components in simple formulas. For instance, the perovskite structure proves to be possessed by the following compounds of formula-type ABX_3: $CaTiO_3$, $SrTiO_3$, $BaTiO_3$, KIO_3, $NaCbO_3$, $CaZrO_3$, $CaSnO_3$, $FeMnO_3$, $KMgF_3$, $LaAlO_3$, $LaGaO_3$. The ionic radii of the components of all these substances stand in relation to each other in accordance with the formula $R_A + R_X = \alpha \cdot \sqrt{2} \cdot (R_B + R_X)$, the coefficient α lying between 0.8 and 1.0. When for any combination of atoms α sinks below 0.8, the atoms take up instead the corundum type of space-lattice, as a result of the increased counter-deforming influence of component A. When on the other hand α rises above 1.0, the calcite type of space-lattice is taken up, and with still greater increase the aragonite type. As the result of numerous observations and calculations it may be stated that:

9. Isomorphous miscibility, to appreciable extent and at temperatures well removed from the melting-point curve, occurs when the radii of the crystal-components concerned differ from one another by not more than about 15%.

10. Even ions of quite dissimilar electronic structure (such as Cd^{++} and Ca^{++}) can replace one another in the simplest types of space-lattices.

C. 2. Antisomorphism.

This term is suggested to describe the case where the points of a given space lattice are occupied by atoms of opposite charges; for instance, CaF_2 and Li_2O have the same arrangement, the two cases being termed the fluorite and the antifluorite space-lattice-type, respectively.

10. In antisomorphous crystals mutual isomorphous miscibility apoears to be excluded.

C. 3. POLYMERIC ISOMORPHISM

This term refers to cases where a substance with a certain formula is isomorphous with another which has a multiple of that formula, as in the case of rutile, TiO_2 and the "trirutiles" $FeCb_2O_6$ and $FeTa_2O_6$, as well as the "polyrutiles" $ZrSiO_4$ and YPO_4.

11. In polymeric-isomorphous crystals mix-crystal formation is possible.

D. LAWS CONCERNING POLYMORPHISM AND MORPHOTROPISM.

A simple way of regarding polymorphism is to consider that as the temperature and pressure under which a compound exists change, the radii and deformabilities of its components vary; for a time the substance remains isomorphous with itself, but ultimately a point is reached at which one or the other of these factors exceeds the limits of stability for that particular structure, and a new arrangement is taken up. Accordingly,

12. The chemico-crystallographic phenomena of isomorphism, morphotropism, and polymorphism are most intimately connected with one another. Polymorphism is the morphotropic structure-change, chemical relations remaining constant, conditioned by the influence of thermodynamic factors on the properties and reciprocal effects of the crystal-components; polymorphism occurs, as soon as the limiting-values for self-isomorphism are overstepped.

13. At higher temperatures that type of crystal-structure is stable which can be obtained through substitution of the counter-deforming cation by its next lower homolog.

A few details as to the observational data on which these various theorems are based are given in the article under review, but the bulk of the evidence is contained in a series of papers on the "Geochemical distribution laws of the elements" by Goldschmidt and his collaborators in course of publication in the *Skrifter norske Videnskap-Akademi*, Oslo, 1923–1926.

"I believe," writes Professor Goldschmidt in conclusion of the essay under review, "to have in this communication shown the way in which chemical-crystallography becomes, instead of a mere descriptive, an exact science." He has certainly done crystallographers a great service in having carried out such an extensive series of x-ray measurements on members of isomorphous series as to make possible the recognition of the principles governing isomorphous replacement. He has given the final death-blow to the older view that valence has a direct connection with isomorphism, as a glance at the series of compounds enumerated under the discussion of theorem 8 will clearly show. With the majority of the ideas put forward the reviewer is in complete accord.[2] The atomic and ionic radii used by Goldschmidt are however, hardly as well established as is implied by the assurance with which they are used, and the reviewer ventures to express the opinion that the values given for the ions of the halogens and oxygen (discussion of theorem 2) will ultimately be found to be about as much too high as those in present use by many workers (the Bragg values of 1920) are too low. If such is the case some of the conclusions as to commensurability of different space-lattice-types (theorem 5), marked deformability of certain crystal-components, (theorem 6), etc., may have to be revised. On the whole, however, Professor Goldschmidt's series of papers, summarized in this essay, represents the most important contribution to chemical crystallography which has appeared since X-rays have been applied to the elucidation of crystal structure.

E. T. WHERRY

PROCEEDINGS OF SOCIETIES

NEWARK MINERALOGICAL SOCIETY

The eighty-fourth regular meeting of the Newark Mineralogical Society was called to order by President T. I. Miller, eighteen members being present. The minutes of the last meeting were read and approved. The secretary reported a total membership of seventy-four with several applications for membership pending. The treasurer reported a satisfactory balance on hand. The special Museum Committee reported that an exhibit would be held at the Newark Museum on December

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[2] He had already arrived at some of them independently, as indicated in articles published in this journal.

15, consisting of specimens obtained from New Jersey localities. At the present time there is displayed at the Museum a collection of radio-active minerals, arranged by Capt. Miller.

The By-Laws Committee presented the new By-Laws, revised to conform to the State incorporation laws. The report was adopted as read. The officers of the Society elected for 1927 are as follows: President, Herbert L. Thowless; Vice-President, Daniel T. O'Connell; Secretary, William H. Broadwell; Treasurer, Herman M. Lehman; Trustees, three year term, J. A. Grenzig; two year term, Mrs. T. I. Miller; one year term, G. E. Carpenter.

Mr. Broadwell then explained the exhibit for the meeting which consisted of mineral labels and trays. These comprised a complete set as used by himself, together with specimen labels from Ward's, English, Hopping, British Museum, and labels used by several other collectors. He emphasized the fact that all collectors should have a label of uniform size and printing, and stated that labels for the United States specimens should be of a different color from those of foreign localities. His card index contained six colors. He also exhibited trays of his own manufacture, made of one piece of good 10-ply coated stock and strong enough for the heaviest specimen.

Capt. Miller then spoke on the display of labels, trays, glass covered boxes, goniometers, etc., exhibited by request by Ward's Natural Science Establishment of Rochester, New York.

Wm. H. Broadwell, *Secretary*

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences of Philadelphia, Nov. 4, 1926.

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with the president, Mr. Vaux, in the chair. Twenty-eight members and seven visitors were present.

Dr. W. S. Newcomet was elected to membership and Mr. L. Weagle to junior membership.

Mr. Frank J. Keeley addressed the society on "*Microscopic mineralogy and the George W. Fiss collection.*" Early in the 1880's minerals were first mounted for display under the microscope, by Mr. Fiss and possibly also Mr. Rakestraw, working independently. The speaker's long association with Mr. Fiss enabled him to give a particularly interesting and intimate description of the manner in which the Fiss collection was brought together and the personalities involved in it. Today the Fiss collection is probably the finest collection of microscopic minerals in existence.

Mr. Keeley also reported the results of his observations with the microspectroscope. It was found that the bright red line in the spectrum of the ruby is a fluorescence line superimposed on a continuous absorbtion band at the red end. On the basis of differences in the absorbtion spectra in the yellow, the following cerium-bearing minerals may be identified one from another: parisite, cordylite or ancylite, rinkite, monazite, tysonite, britholite, lanthanite and rhabdophanite.

Mr. Trudell described a trip which he took with several others to the French Creek mines. Pyrite and green calcite crystals were exhibited.

F. A. Cajori, *Secretary.*